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(54) **TOUCH SENSITIVE DEVICE WITH MULTI-SENSOR STREAM SYNCHRONIZED DATA**

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(58) **Field of Classification Search**

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See application file for complete search history.

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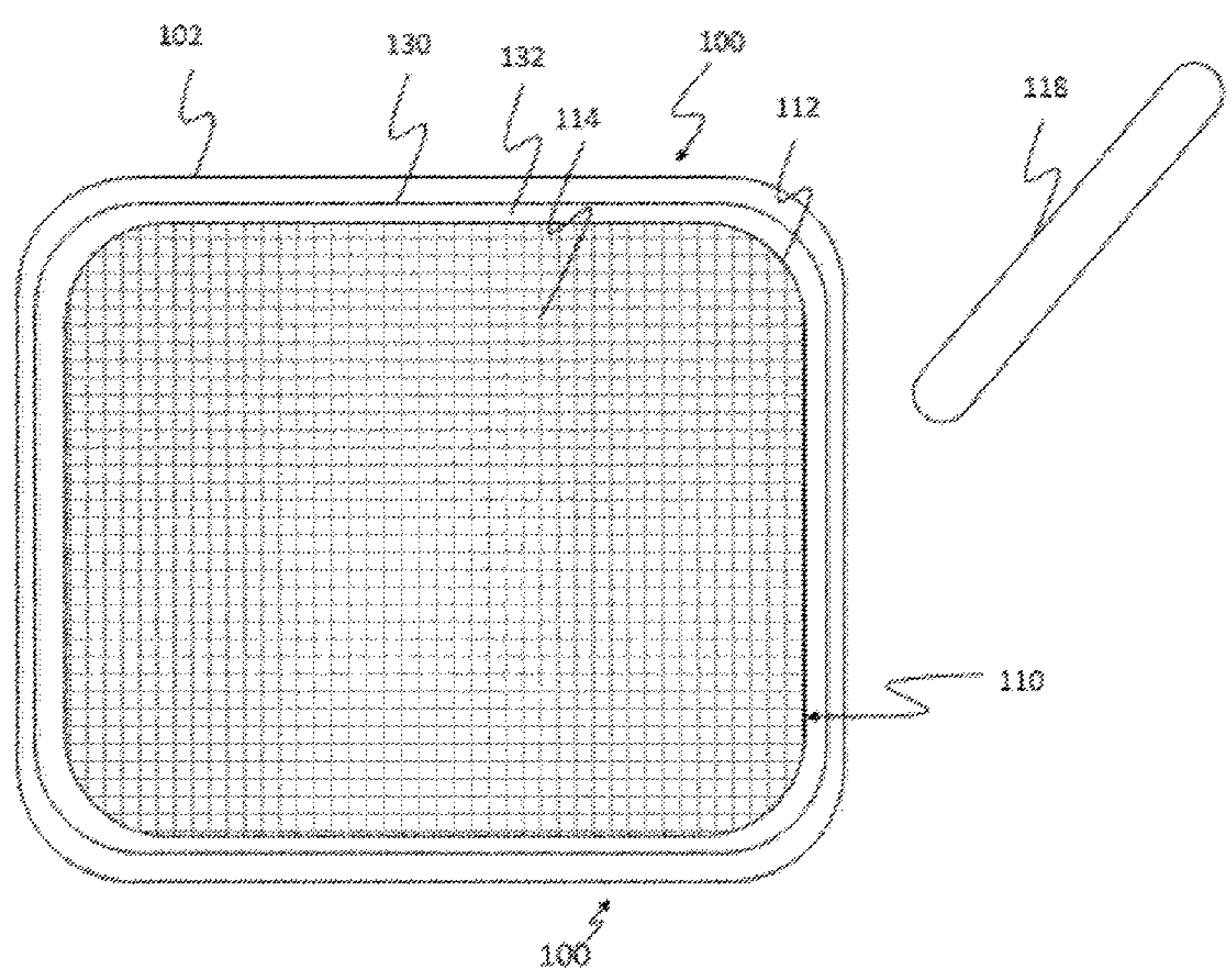
(57) **ABSTRACT**

Touch sensitive devices having sensor systems and sensor systems for use with touch sensitive devices are provided. A vibration sensor senses vibrations and a touch sensor senses contact with an object. Vibration data representing sensed vibration is stored in a sensor data memory and touch data indicative of contact between the object and the touch sensitive surface is stored in the sensor data memory in temporal association with the vibration data. The touch data and the temporal association with vibration data can be used to identify segments of the vibration data that are of interest.

19 Claims, 10 Drawing Sheets



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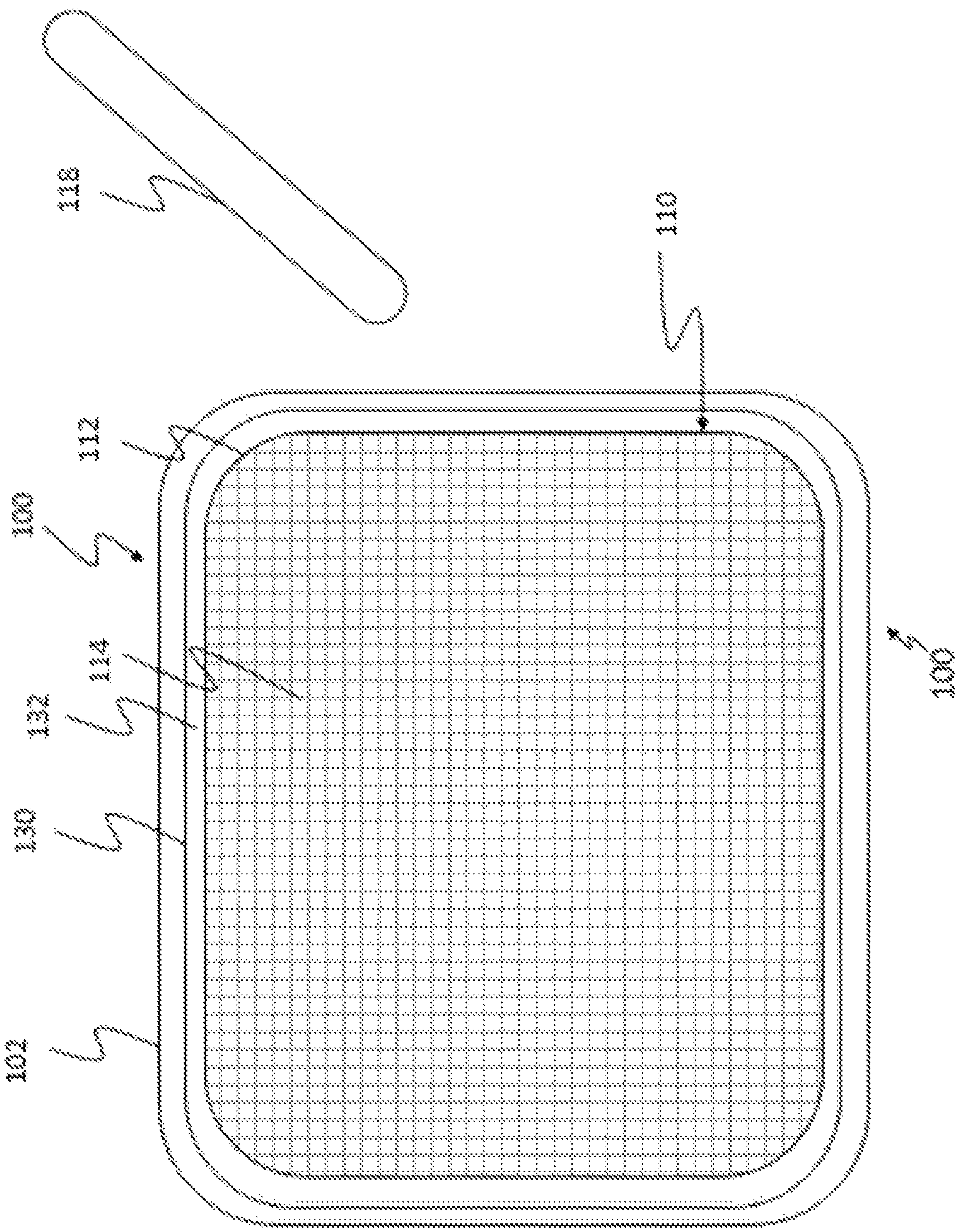
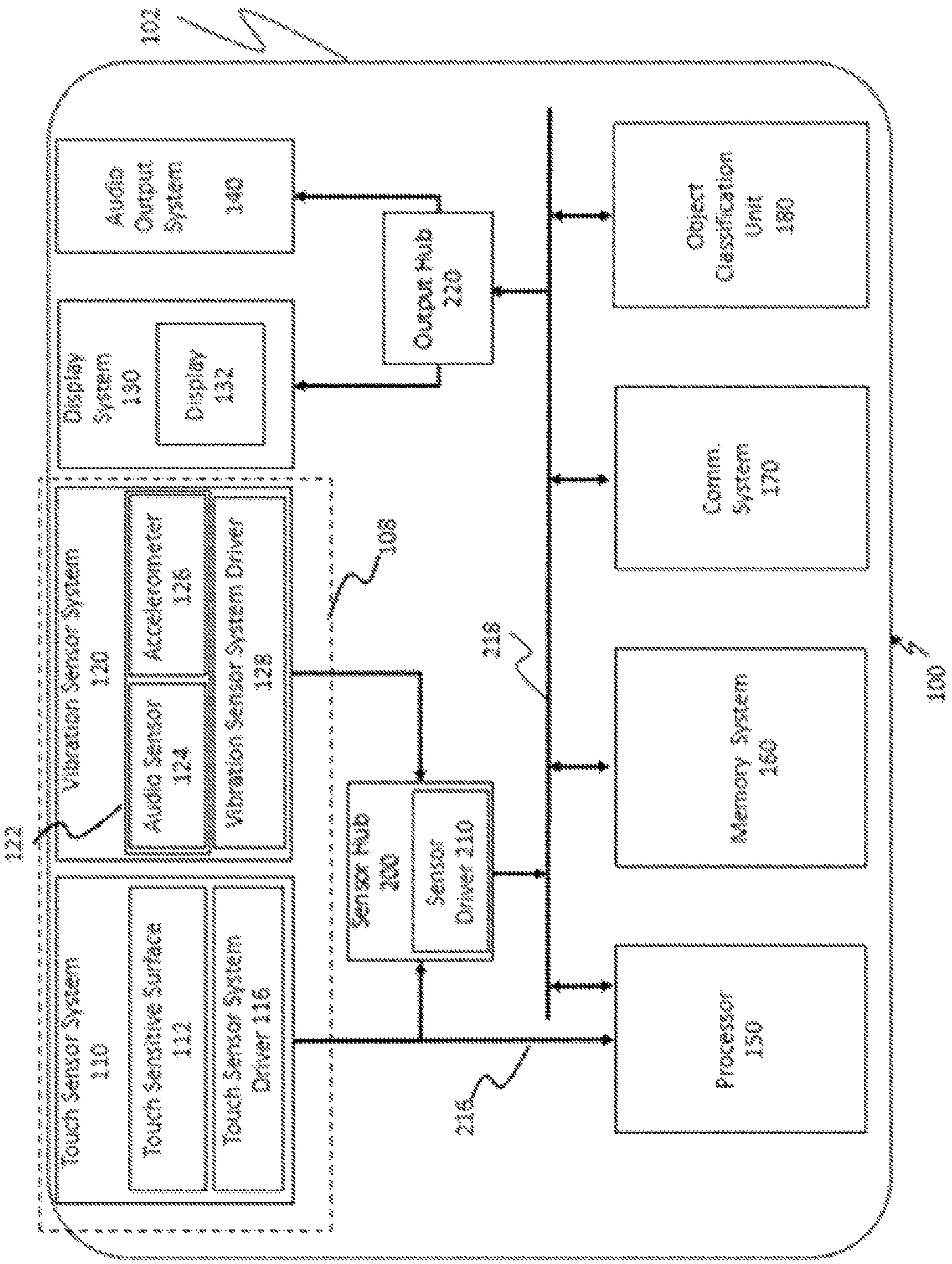


FIG. 1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Audio Sensor 124
Vibration Sensor System Driver 128
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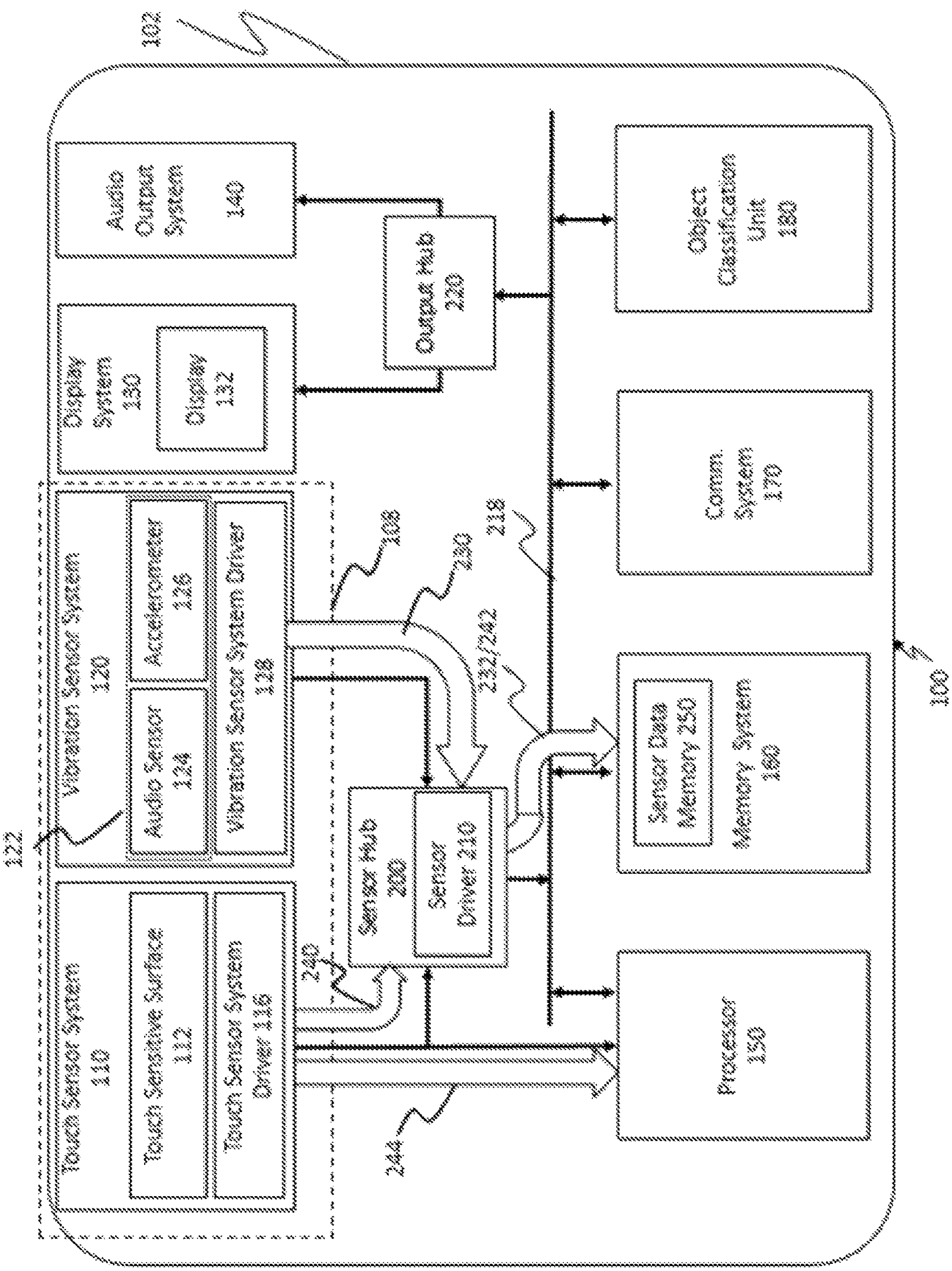
Touch Sensitive Surface 112
Touch Sensor System Driver 116
Sensor Hub 200
Sensor Driver 210
218
216
Object Classification Unit 180
Comm. System 170
Memory System 160
Processor 150
100

FIG. 2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108
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232/242
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Touch Sensitive Surface 112
Touch Sensor System Driver 116
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Processor 150
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FIG. 3

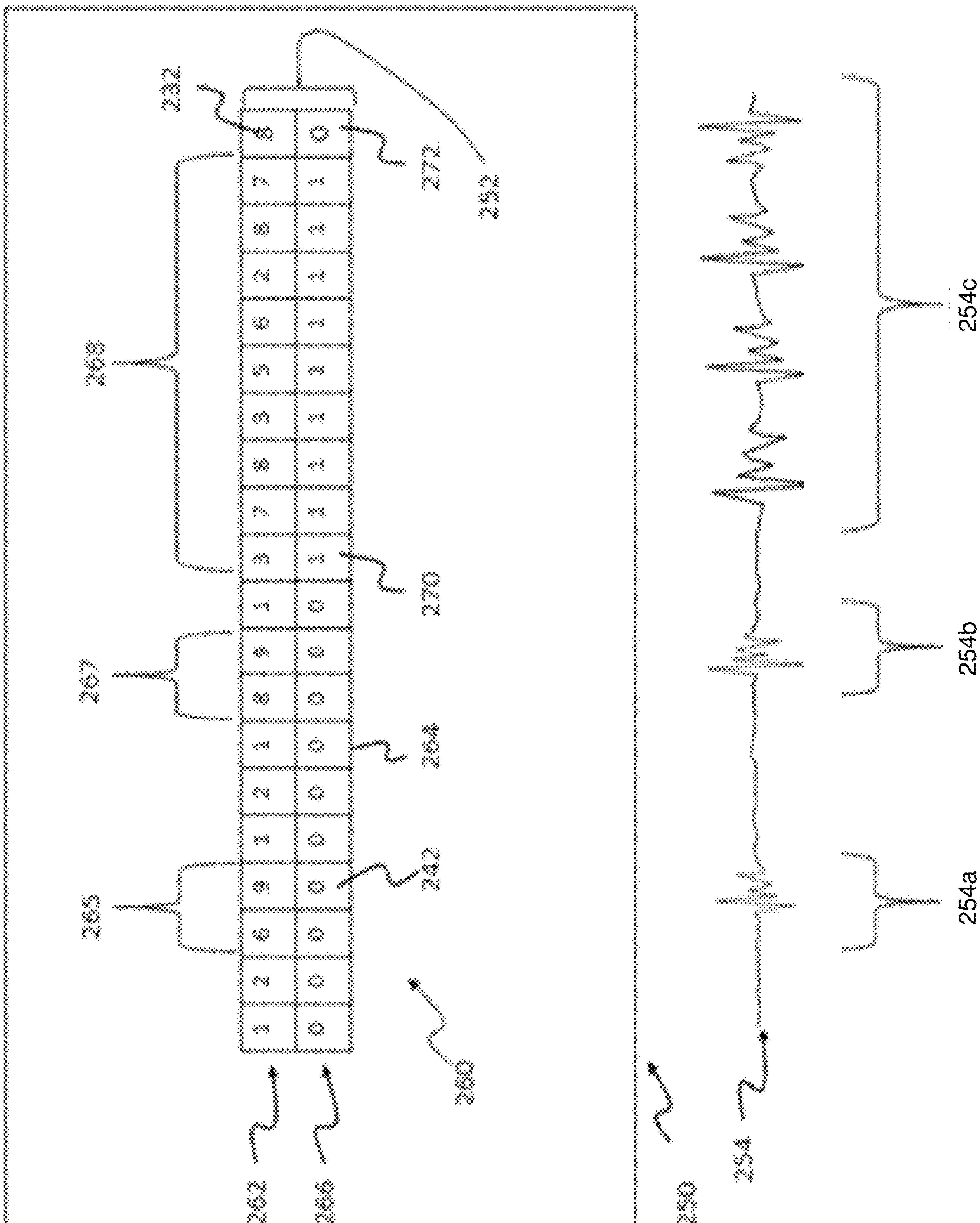
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Fig. 4

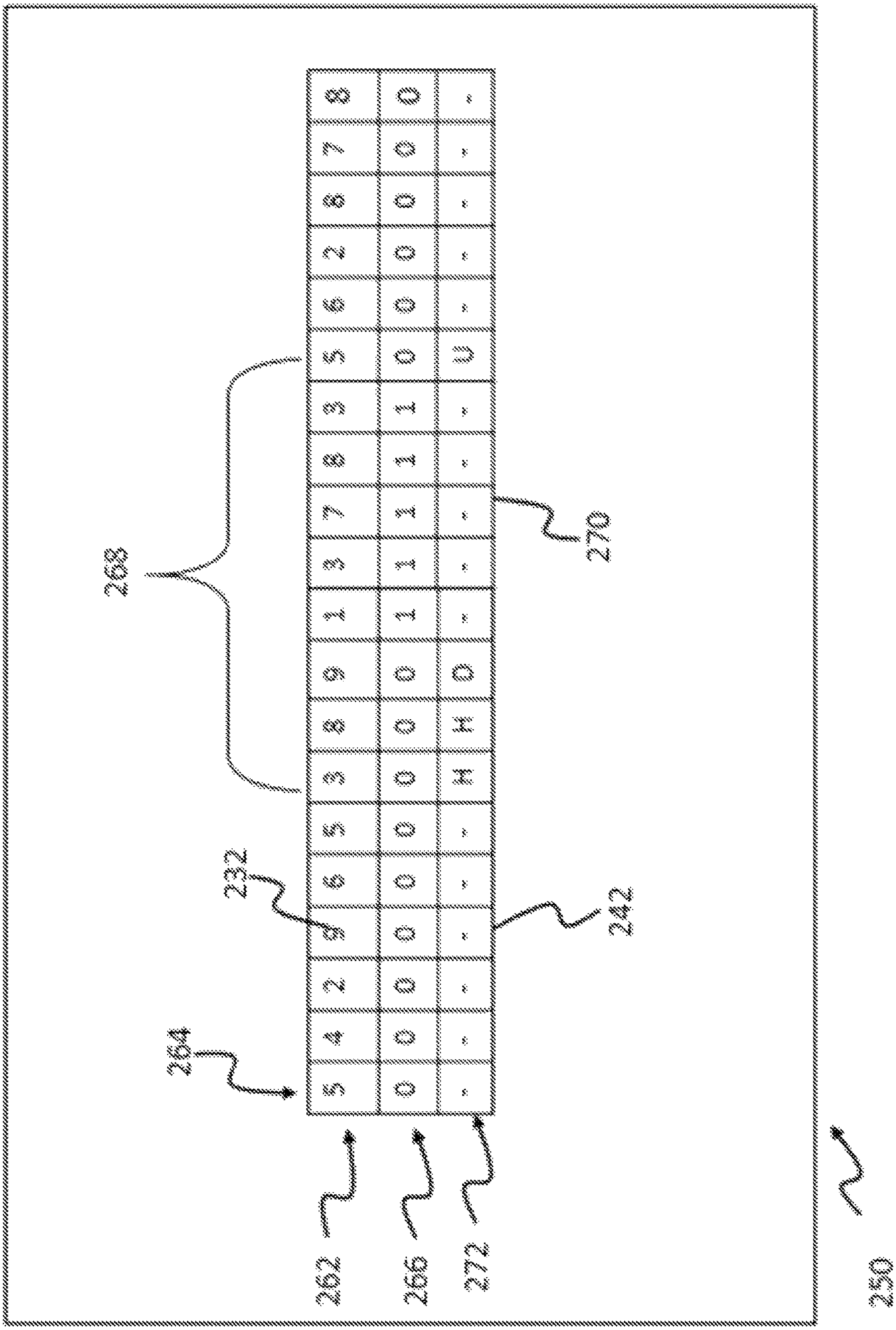
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FIG. 5

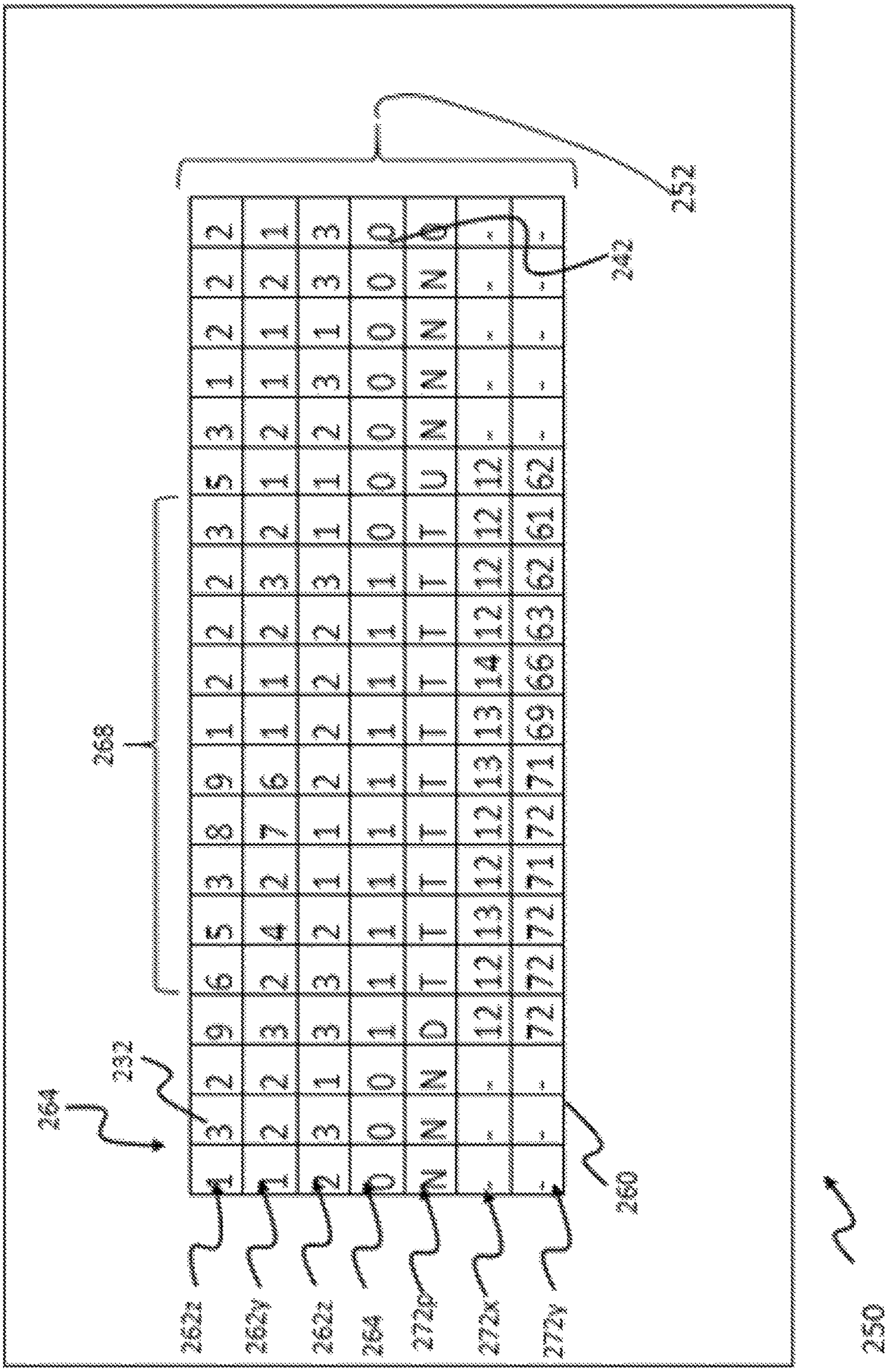
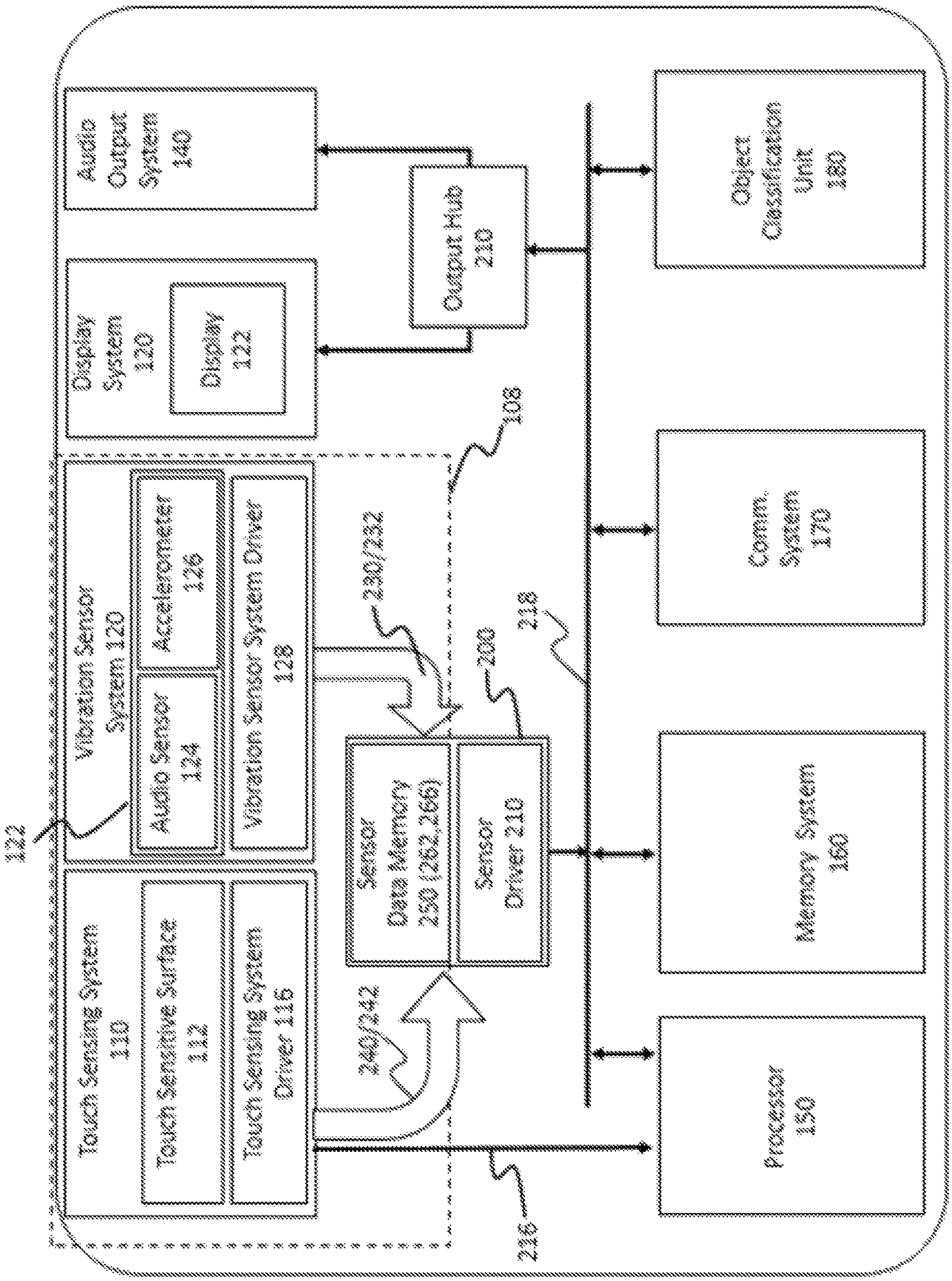


FIG. 6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218
Comm. System 170
122
Touch Sensing System 110
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Touch Sensing System Driver 116
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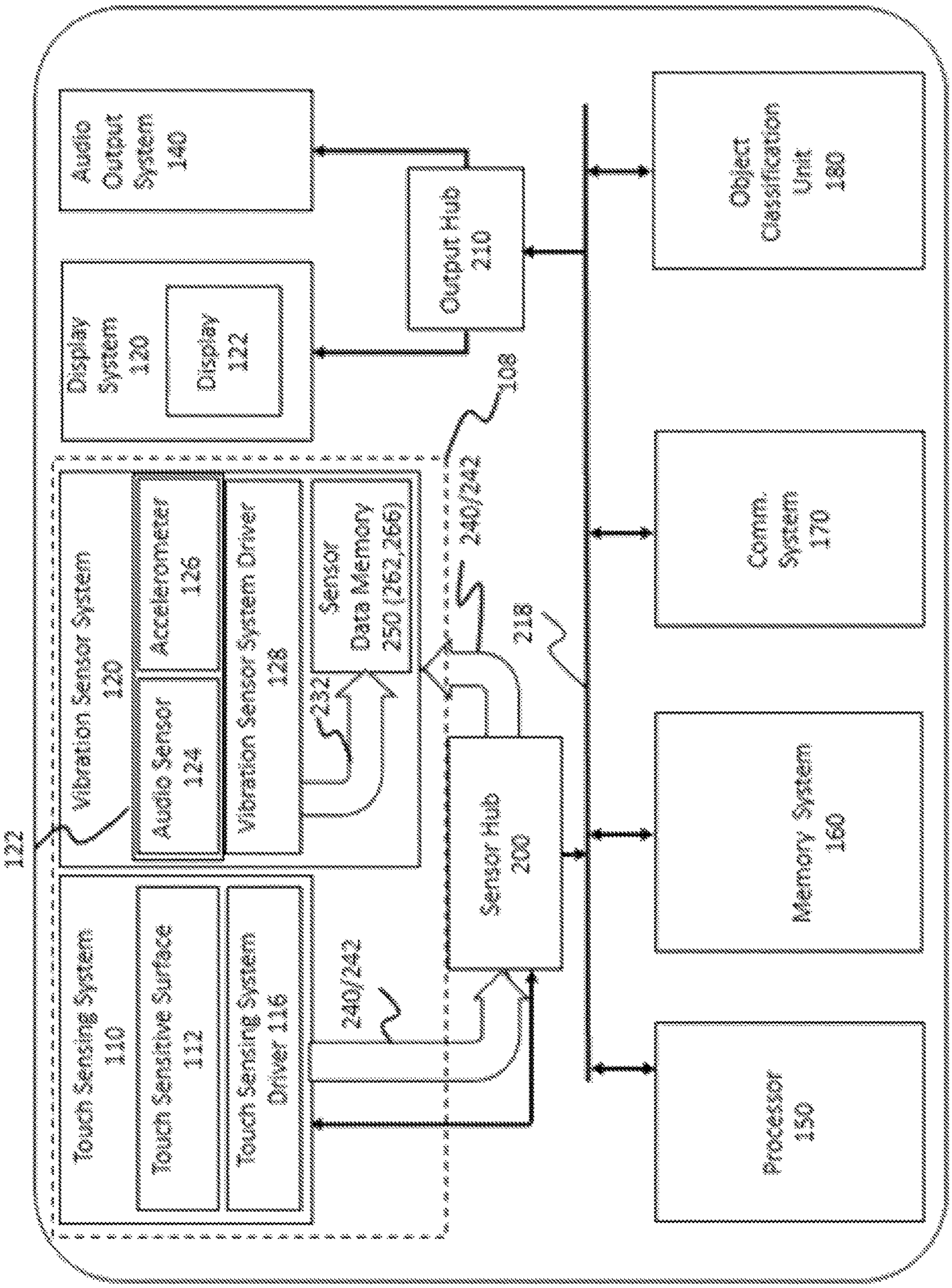
Sensor Driver 210
Memory System 160
240/242
Processor 150
216

FIG. 7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232
240/242
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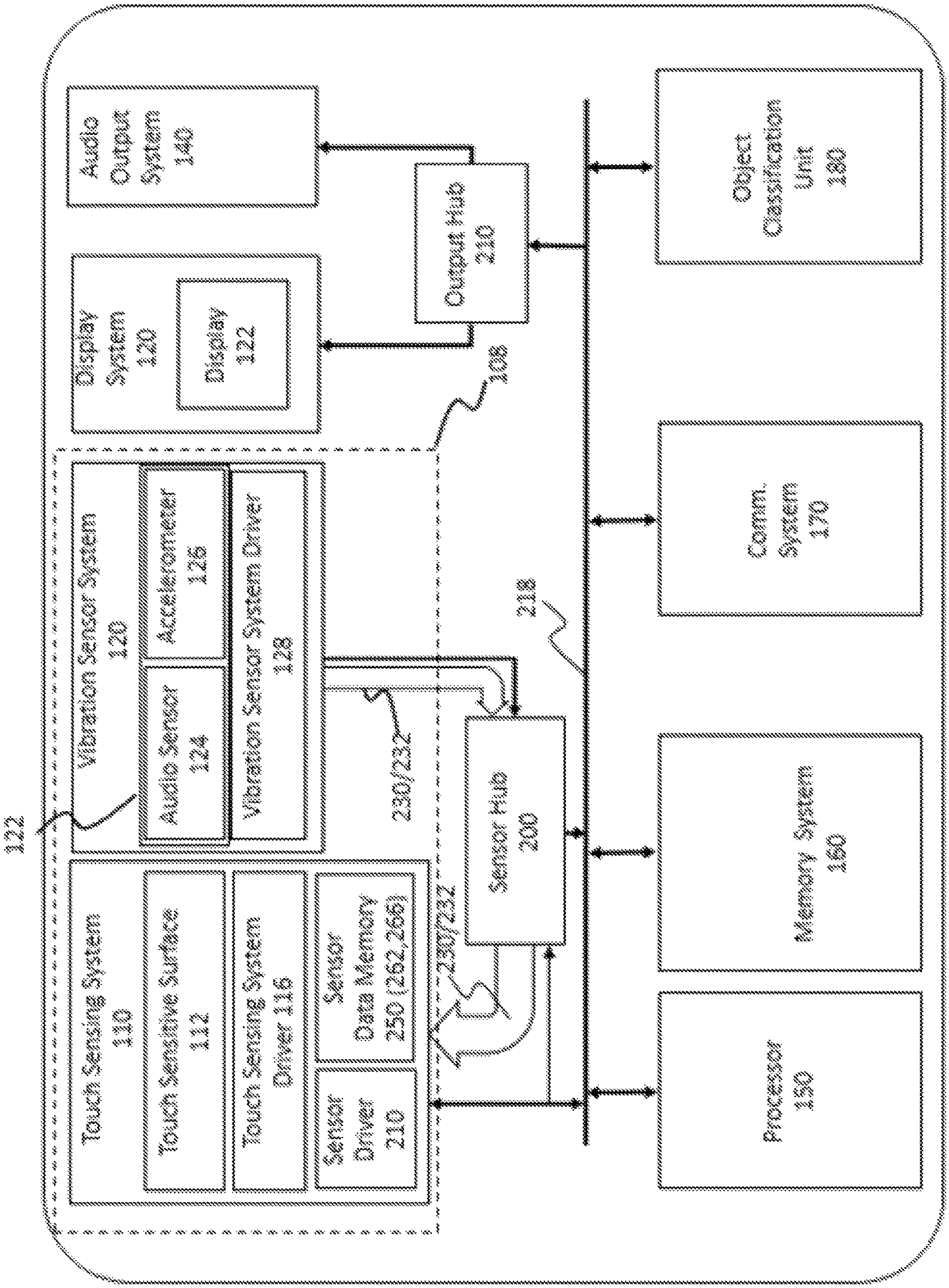
Display 122
Output Hub 210
Audio Output System 140
Processor 150
Memory System 160
Comm. System 170
Object Classification Unit 180

FIG. 8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Comm. System 170
Sensor Hub 200
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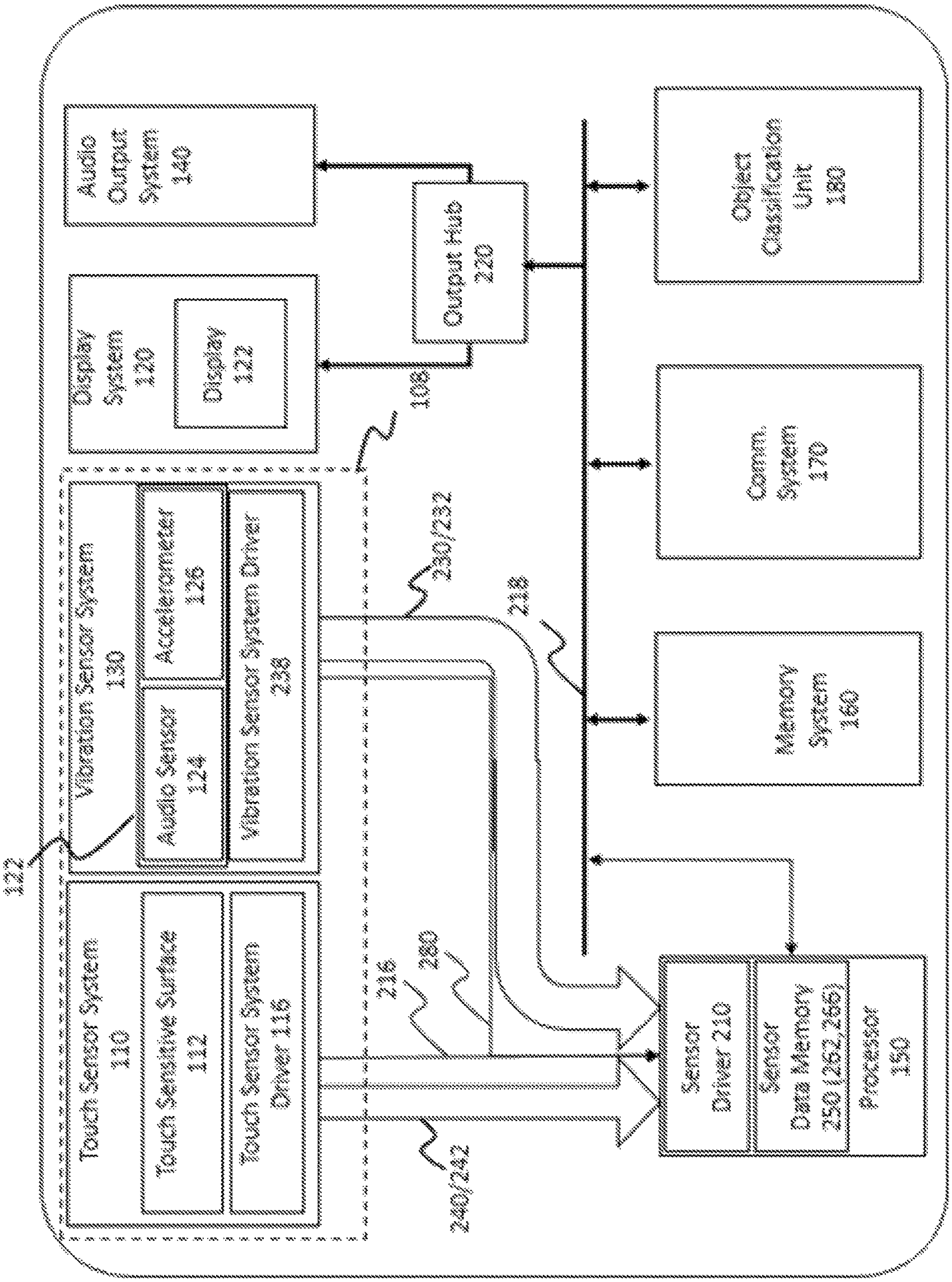
Sensor Driver 210
230/232
Memory System 160
Processor 150

FIG. 9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122
230/232
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Touch Sensor System 110
Touch Sensitive Surface 112
Touch Sensor System Driver 116
216
280
240/242
Sensor Driver 210
Sensor Data Memory 250 (262, 265)
Processor 150

FIG. 10

TOUCH SENSITIVE DEVICE WITH MULTI-SENSOR STREAM SYNCHRONIZED DATA

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TECHNICAL FIELD

The present invention relates generally to the field of touch sensing technology and more particularly to a method, apparatus and system for sensing touch contact with a surface.

BACKGROUND

The subject matter discussed in the background section should not be assumed to be prior art merely as a result of its mention in the background section. Similarly, a problem mentioned in the background section or associated with the subject matter of the background section should not be assumed to have been previously recognized in the prior art. The subject matter in the background section merely represents different approaches, which in and of themselves may also be inventions.

Various electronic devices today are typically operated by a user interacting with a touch screen. This feature is particularly a characteristic of the recent generation of smart phones. Typically, touch screen display screens respond to finger contact to activate the display for further processes. Contact may also be made using tools such as a stylus, other parts of the hand such as the palm and various parts of the finger. Smartphone manufacturers continuously develop new techniques to improve smartphone user experience.

SUMMARY OF THE INVENTION

Touch sensitive devices and sensor systems for use with touch sensitive devices are provided. In one aspect, the touch sensitive device has a touch sensor system having a touch sensitive surface that senses contact between the touch sensitive surface and an object and that generates touch signals indicative of the sensed contact, a vibration sensor system that senses vibrations that occur incident to the contact between the touch sensitive surface and the object and that generates vibration signals indicative of the sensed vibrations and a sensor data memory. At least one controller is adapted to receive the vibration signals and to cause data indicative of vibrations sensed during each of a plurality of sample periods to be stored in a vibration data record in the sensor data memory. The controller is further adapted to receive the touch signals and to cause data to be stored in the sensor data memory in temporal association with the vibration data record from which a processor can identify a segment of the vibration data record related to the contact based upon the touch data record and the temporal association.

BRIEF DESCRIPTION OF THE DRAWINGS

The included drawings are for illustrative purposes and serve only to provide examples of possible structures and process steps for the disclosed techniques. These drawings in no way limit any changes in form and detail that may be made to embodiments by one skilled in the art without departing from the spirit and scope of the disclosure.

FIG. **1** illustrates an example touch sensing device having a touch sensitive surface, in accordance with some embodiments of the invention.

FIG. **2** illustrates an example touch sensitive device having a touch sensitive surface, in accordance with some embodiments of the invention.

FIG. **3** illustrates an example of the touch sensitive device of FIG. **2** with data flows, in accordance with some embodiments of the invention.

FIG. **4** illustrates an example of a sensor data memory and a vibrational stimulation, in accordance with some embodiments of the invention.

FIG. **5** illustrates another example of a sensor data memory, in accordance with some embodiments of the invention.

FIG. **6** illustrates another example of a sensor data memory, in accordance with some embodiments of the invention.

FIG. **7** illustrates another example of a touch sensitive device, in accordance with some embodiments of the invention.

FIG. **8** illustrates another example of a touch sensitive device, in accordance with some embodiments of the invention.

FIG. **9** illustrates another example of a touch sensitive device, in accordance with some embodiments of the invention.

FIG. **10** illustrates another example of a touch sensitive device, in accordance with some embodiments of the invention.

DETAILED DESCRIPTION OF THE INVENTION

Applications of methods and apparatus according to one or more embodiments are described in this section. These examples are being provided solely to add context and aid in the understanding of the present disclosure. It will thus be apparent to one skilled in the art that the techniques described herein may be practiced without some or all of these specific details. In other instances, well known process steps have not been described in detail in order to avoid unnecessarily obscuring the present disclosure. Other applications are possible, such that the following examples should not be taken as definitive or limiting either in scope or setting.

In the following detailed description, references are made to the accompanying drawings, which form a part of the description and in which are shown, by way of illustration, specific embodiments. Although these embodiments are described in sufficient detail to enable one skilled in the art to practice the disclosure, it is understood that these examples are not limiting, such that other embodiments may be used and changes may be made without departing from the spirit and scope of the disclosure.

One or more embodiments may be implemented in numerous ways, including as a process, an apparatus, a system, a device, a method, a computer readable medium such as a computer readable storage medium containing computer readable instructions or computer program code, or as a computer program product comprising a computer usable medium having a computer readable program code embodied therein.

The figures in the following description relate to preferred embodiments by way of illustration only. The figures are not necessarily to scale. It should be noted that from the following discussion, alternative embodiments of the structures and methods disclosed herein will be readily recognized as viable alternatives that may be employed without departing from the principles of what is claimed.

FIG. **1** illustrates an exterior view of one embodiment of a touch sensitive device **100** and FIG. **2** shows a block diagram of touch sensitive device **100**. In this embodiment, touch sensitive device **100** takes the form of a touch sensitive cellular telephone having housing **102** holding a sensor system **108** with a touch sensor system **110** and a vibration sensing system **120**, a display system **130**, an audio output system **140**, a processor **150**, a memory system **160**, a communication system **170** and an optional object classification unit **180**.

As is shown in FIG. **2**, in this embodiment, a sensor hub **200** has a sensor driver **210** that receives signals from sensor system **108** and makes information from the signals available to processor **150**, memory system **160**, communication system **170** and optional object classification unit **180** while an output hub **220** receives signals from processor **150** and provides signals to display system **130** and audio output system **160** in accordance with the signals received from processor **150** and a main bus **218** connects sensor hub **200**, output hub **220**, processor **150**, memory system **160**, communication system **170** and object classification unit **180**. Direct connections between individual components can be made. For example, a direct connection **216** between touch sensor system **110** and processor **150** is shown in this embodiment.

Touch sensor system **110** has a touch sensitive surface **112** that is adapted to detect when an object **118** such as a fingertip, body part, or stylus is positioned in contact with touch sensitive surface **112** and to generate a signal from which it can be determined which portion of touch sensitive surface **112** is in contact with object **118**.

In this embodiment, touch sensitive surface **112** has a plurality of touch sensing elements **114**. Each of elements in the array of sensing elements **114** are associated with a predetermined portion of touch sensitive surface **112** and are capable of sensing contact with object **118**. Sensing elements **114** can be of any known type. Common sensing elements can include capacitive sensing elements that detect changes in capacitance as an object approaches or contacts sensing elements **114** and resistive sensing elements that detect changes in resistance caused by contact between object **118** and touch sensitive surface **112**. Any other type of sensing can be used for this purpose.

For convenience object **118** will be referred to herein in the singular form however, it will be appreciated that touch sensitive surface **112** may be of a "multi-touch" type that is capable of detecting when multiple objects **118** are in contact with touch sensitive surface **112**.

In the embodiment that is illustrated in FIGS. **1** and **2**, touch sensor system **110** has a touch sensor system driver **116** that sweeps array of sensing elements **114** or otherwise samples each element in array of sensing elements **114** to determine which portions of touch sensitive surface **102** were in contact with object in a given period of time. The period of time can be any period, however, for example and without limitation the period of time can be $1/30^{th}$, $1/60^{th}$ or $1/100^{th}$ of a second. Touch sensor signals are then generated from which it can be determined which portions of touch sensitive surface **112** were in contact with object **118** during the period of time. These signals can take the form of frame data that can be stored, for example, in digital form for use by other systems inside or outside of touch sensitive device **100**. Touch sensor system driver **116** in some embodiments may generate other signals indicative of contact against touch sensitive surface **112** such as signals that are indicative of contacts between touch sensitive surface **114** during a sample. Touch sensor system **116** may also generate signals that are indicative of proximity of object **118** to touch sensitive surface **114** such as may occur when capacitive sensing elements are used for touch sensitive surface **112** as such touch sensitive elements can detect proximity prior of certain objects to touch sensitive surface **112** to contact. Other forms of proximity sensing may be used.

In this embodiment, touch sensitive device **100** further has a memory system **160**. Memory system **160** is capable of storing frame data and may be capable of storing programs, executable algorithms, computer readable instructions or computer program code and other forms of instructions that can be executed by a processor **150** and may also be used for other purposes. Memory system **160** may include read only memory, random access semiconductor memory or other types of memory or computer readable media that may be permanently installed or separably mounted to touch sensitive device **100**. Additionally, touch sensitive device **100** may also access a memory system **160** that is separate from touch sensitive device **100** by way of an optional communication system **170**.

Processor **150** shown in the embodiment of FIGS. **1** and **2** can take the form of any device capable of performing the functions described herein including but not limited to a computer, micro-processor, micro-controller, programmable analog logic device, or a combination of devices and can be a stand-alone device or combination of devices.

Sensor system **108** can take any of a variety of forms and can comprise generally any known device for sensing conditions inside or outside of touch sensitive device **100**. Sensor system **108** can, without limitation, include acoustic sensors, accelerometers, gyroscopes, light sensors, range finders, proximity sensors, barometer, touch input sensors, thermometers, Hall effect sensors, switches such as 2-way, 4-way switch, a 6-way switch, an 8-way switch, mouse and trackball systems, a joystick system, a voice recognition system, a video based gesture recognition system or other such systems, radio frequency identification and near field communication sensors, bar code sensors, position sensors and other sensors known in the art that can be used to detect conditions that may be useful to in governing operation of touch sensitive device **100** and to convert this information into a form that can be used by processor **140**. Sensor system **108** may also include biometric sensors adapted to detect characteristics of a user that can be used, for example for security, medical and affective determinations.

Alternatively or additionally, vibration sensor system **120** can include vibration sensors, ultrasonic sensors, piezoelectric devices or other known circuits and systems that can sense vibrations such pressure waves carried by air surrounding touch sensitive system **100** such as acoustic signals or sounds, and/or acoustic signals that can carry mechanical vibrations carried through structures of touch sensitive device **100** or object **118** including but not limited to those that are indicative of contact between an object **118** and touch sensitive surface **112**

Examples of sensor types that can be used to sense vibrations and that may be used as vibration sensors in a vibration sensor system **120** useful in operating a touch sensitive device include but are not limited to:

Piezoelectric bender elements;

Piezoelectric film;
Accelerometers (e.g., linear variable differential transformer (LVDT), Potentiometric, Variable Reluctance, Piezoelectric, Piezoresistive, Capacitive, Servo (Force Balance), MEMS);
Displacement sensors;
Velocity sensors;
Vibration sensors;
Gyroscopes;
Proximity Sensors;
Electric microphones;
Hydrophones;
Condenser microphones;
Electret condenser microphones;
Dynamic microphones;
Ribbon microphones;
Carbon microphones;
Piezoelectric microphones;
Fiber optic microphones;
Laser microphones;
Liquid microphones; and,
MEMS microphones

Optionally, both in-air vibrations or pressure waves and vibrations of components of touch sensitive device **100** can be sensed by vibration sensor system **120** (e.g., one for in-air acoustics, and one for mechanical vibrations, also referred to as structural acoustics). For example the embodiment illustrated in FIG. **2**, touch sensitive device **100** has an audio sensor **124** for sensing in-air acoustics and an accelerometer **126** or sensing structural acoustics. Touch sensitive device **100** may use a sensing system **120** having a virtual or wireless connection to a microphone. In this embodiment, vibration sensing system **120** is also shown having an accelerometer **126**.

It will be appreciated that many popular touch sensitive devices **100** such as cellular telephones and tablet computers are configured with both an audio sensor **124** and an accelerometer **126** for purposes such as voice communication and motion sensing. Such built in sensors can be utilized without the need for additional sensors, or can work in concert with sensors that are incorporated into touch sensitive device **100** primarily for the purpose of detecting conditions that may provide useful information in the interpretation of user input actions.

Vibration sensor system **120** can also include pressure sensors that can sense an amount of pressure applied by object **118** against touch sensitive surface **112**. In some embodiments of this type touch sensitive surface **112** can be of a type that can sense not only which portion of touch sensitive surface **112** has been contacted by object **118** but the amount of pressure applied against touch sensitive surface. Various technologies of this type are known examples of which include, but are not limited to graphics tablets sold under the Wacom brand by Wacom Co., Ltd., Kazo, Saitama, Japan and that are presently capable of sensing **1024** different levels of pressure.

Optionally, vibration sensor system **120** can include one or more sensors that can be incorporated in or on object **118** and that can sense conditions indicative of an amount of force applied between object **118** and touch sensitive surface **112**. In such embodiments, vibration sensor system **120** can include a force sensor that can take the form of, for example and without limitation, a piezoelectric sensor, a stress sensor, a strain sensor, a compression sensor, a deflection sensor, or resiliently biased sensing system that can sense force based on an extent of deflection movement of a contact surface against the force of the resilient member and that can generate a signal that is indicative of the amount of force applied by or through an indicator against touch sensitive surface **112**.

A vibration sensor system **120** having a sensor in or on object **118** can send signals indicative of an amount of force between object **118** and touch sensitive surface **112** by way of a wired connection or a wireless connection such as by an optional wireless communication module that is capable of communication with communication system **170**.

In further embodiments, force sensing can be achieved by providing an object **118** such as a stylus as illustrated in FIG. **1**, that may in some embodiments have a rounded flexible tip such as a rubber or metallic mesh tip that are arranged in a resilient manner to flatten when pressed against touch sensitive surface **112** increasing the amount of surface area in contact with touch sensitive surface **112**. In such embodiments, the size of the area in contact with touch sensitive surface **112** is an effective proxy for the amount of force applied by a user against touch sensitive surface **112** and in this regard a touch sensitive surface that is capable of sensing area that is in contact with touch sensitive surface **112** can be used for this purpose. Similar results can be achieved, with proper calibration, using a fingertip or other such object **118**.

In the embodiment that is shown in FIG. **2**, vibration sensor system **120** has a vibration sensor system driver **128** adapted to sample the sensors of vibration sensor system **120** during sensor sample periods and to generate vibration signals **230** that are indicative of conditions at the vibration sensor(s) during the vibration sensor sample periods. Vibration signals **230** can be in analog or digital form and may be processed, amplified, modulated, or otherwise adjusted by vibration sensor system driver **128**.

Communication system **170** can take the form of any optical, radio frequency or other circuit or system that can convert data into a form that can be conveyed to an external device by way of an optical signal, radio frequency signal or other form of wired or wireless signal. Communication system **170** may be used for a variety of purposes including but not limited to sending and receiving instruction sets and exchanging data with remote sensors or memory systems.

Sensor hub **200** receives signals from touch sensor system **110** and vibration sensor system **120** makes these signals or data derived from these signals available to other components of touch sensitive device **100**. In the embodiment that is illustrated in FIG. **2**, sensor hub **200** is arranged to receive signals from touch sensor system **110** and vibration sensor system **120** and has a driver that prepares the signals for transmission through main bus **230** to other components of touch sensitive device **100**. In other embodiments, sensor hub **200** can be connected directly to touch sensor system **110** and vibration sensor system **120** and to components of touch sensitive system **110** such as memory system **160**, communication system **170** or on optional object classification unit **180**.

Sensor hub **200** can optionally process signals received from touch sensor system **110** and vibration sensor system **120**. For example and without limitation sensor hub **200** can optionally include analog to digital converters of any known type that can convert analog signals from vibration sensor system **120** into digital signals and may also include amplifiers, filters, including but not limited to noise filters, band pass/band reject filters or couplings, breakers, fusible links or other systems that protect other components of touch sensitive system **100** from potential damage.

Sensor hub **200**, according to one embodiment, may perform a function of interfacing with sensing system **108** to sense a sound or vibration generated when object **118** contacts touch sensitive surface **112**, or, in other embodiments, other specific parts (i.e., the exterior parts) of touch sensitive device **100**.

Output hub **220** is optional and in this embodiment receives signals from processor **150** and optionally other components of touch sensitive system **100** and may use these signals to control operation of display system **130** and audio output system **140** as well as any other output systems that may be incorporated into touch sensitive system. In this regard, output hub **220** may include display drivers, audio output systems including amplifiers and the like.

It will be appreciated that various embodiments of the invention, some or all of the functions ascribed to output hub **220** may be performed by hardware or programs that are integrated in whole or in part in touch sensor system **110** and vibration sensing system **120** including but not limited to touch sensor system driver **116** and vibration sensor system driver **128**.

Contact Interpretation

The task of deriving information from contacts between touch sensitive device **100** and an object **118** can be daunting given the challenge of providing a near instantaneous response to such input and the challenge of ensuring that the input is properly understood. In particular it will be understood that not all contacts against a touch sensitive surface **112** are intended as an input. Incidental contacts and other contacts against touch sensitive surface **112** occur frequently and if interpreted in the same manner as intentional contacts these may cause unintended consequences.

Further, input made using touch sensitive surfaces **112** can be complex. For example, such input can take the form of a stroke type input such as signatures, artistic renderings, as well as common file and data manipulations such as cut and paste manipulations. These inputs may range over a wide portion of the input screen and may occur over a relatively extended time period. Depending on the rate at which frame data is obtained, it may be necessary for processor **140** to evaluate many thousands of frames of data to determine stroke data associated with a single stroke and in the case of multi-point touch sensitive systems it may be necessary to track many contact points across these many frames. This makes interpretation of such input a processor intensive task.

Additionally, there is a wealth of additional information that the touch sensitive device can provide to processor **140** that may be highly beneficial to processor **140** in making determinations regarding the intent of the user in bringing an object **118** into contact with touch sensitive surface **112**.

For example, a touch sensitive device **100** having a touch sensor system **108** with a vibration sensor system **120** such as the one that is illustrated in FIGS. **1** and **2** may be capable of sensing vibrations carried to vibration sensor system **120** through elements of touch sensitive device **100** or vibrations carried to vibration sensing system **120** by way of a medium surrounding touch sensitive device **100** such as acoustic vibrations carried in air or water. Vibration sensor system **120** has at least one vibration sensor that senses the vibrations and provides a vibration signal that is indicative of the sensed vibrations. Optionally, vibration sensor system **120** may have a vibration sensor system driver **128** that amplifies, powers, filters or otherwise prepares the vibration signal for use by processor **150** or sensor hub **200**. In some embodiments vibration sensing system **120** may provide vibration signals in analog form for conversion to digital form by another device such as by way of a sensor hub **200**. Vibration sensor system sensor driver **128** may perform other functions as described or claimed herein.

The vibration signal is used by processor **150** determine vibro-acoustic information that can be used during analysis of a touch event. For example, the vibration signal may yield vibro-acoustic information such as the magnitude of the amplitude of the vibrations occurring incident to a contact between an object **118** and touch sensitive surface **112** signal. However, this is not limiting and processor **150** may use any type of statistical, mathematical, or other logical analysis of the vibration signal to determine vibration information that may be useful in operating touch sensitive device **100**. The use of the term vibro-acoustic information may encompass any information derivable from vibrations sensed incident to a touch event and may include either or both of information derived from vibrations carried in touch sensitive device **100** to a sensor or vibrations carried to a sensor by way of an intermediate medium such as acoustic vibrations carried in the form of air pressure variations, as well as information sensed in any other manner including but not limited to vibration information sensed by touch sensor system **110** and vibration information sensed by external devices.

Such vibro-acoustic information may be useful to help processor **150** to determine the nature of an object that has made contact with touch sensitive surface **112**. One method for doing this is described in commonly assigned and co-pending U.S. patent application Ser. No. 14/612,089, entitled "Method and Apparatus for Classifying Finger Touch Events on a Touch Screen," filed on Feb. 2, 2015, and incorporated by reference herein in its entirety. This application in part describes an apparatus for classifying touch events having a touch sensitive surface configured to generate a touch event when an object or finger touches the touch sensitive surface, wherein the touch event entails a mechanical vibration generated upon contact with the surface, a touch detector configured to detect the onset of a touch and a touch event classifier configured to classify the touch event to identify the object used for the touch event.

Vibro-acoustic information may also be used as described in commonly assigned and co-pending "Capture of Vibro-Acoustic Data used to Determine Touch Types, U.S. patent application Ser. No. 13/958,427 filed on Aug. 2, 2013 and incorporated herein by reference in its entirety. This application describes in part a method for interaction between a user and an electronic device having a touch sensitive surface. In this method a touch event trigger is received that indicates an occurrence of a physical touch event on the touch-sensitive surface. Touch data produced by the touch event is accessed and vibro-acoustic data for a vibro-acoustic signal produced by the physical touch event is accessed for a time window that begins at a time that is prior to receipt of the touch event trigger and a touch type for the touch event is determined based on the touch data and the vibro-acoustic data.

Vibro-acoustic data also may be used as is described in commonly assigned and co-pending U.S. patent application Ser. No. 14/219,919, entitled "Method and Device for Sensing Touch Inputs", filed on Mar. 19, 2014 and incorporated herein by reference in its entirety. This application describes in part, a method for sensing touch inputs to digital equipment in which a sound/vibration signal that is generated by a touch is sensed and the sensed sound/vibration signal is digitally processed. Here the type of touch means as well as a touch intensity is determined based on features derived from time and frequency domain representations of the processed sound/vibration signal.

Additionally, there are vibro-acoustic differences between contact made with a sensing surface when different parts of a input tool contact a touch sensitive surface. These differences are usefully applied in commonly assigned and co-pending U.S. patent application Ser. No. 14/668,870, entitled "Input Tools Having Vibro-Acoustically Distinct Regions and Computing Device For Use With Same," filed on Mar. 25, 2015 and incorporated herein by reference in its entirety. This application describes in part an input tool for interacting with a touch screen, the input tool comprising: a body in the form of a stylus, the body having one or more vibro-acoustically distinct regions, wherein each virbo-acoustically region produces a discrete vibro-acoustic signal when it touches a surface of the touch screen and the virbo-acoustic signal is used to detect what region of the input tool was used. Such vibro-acoustic signals can also be used to discriminate between different types of finger contacts such as contact with the knuckle, fingernail and fingertip as is described in commonly assigned U.S. Pat. No. 9,013,452, entitled "Method and System For Activating Different Interactive Functions Using Different Types of Finger Contact", filed on Mar. 25, 2013 and issued on Apr. 21, 2015 and incorporated by reference in its entirety.

Virbro-acoustic information may also be used to determine which portions of a finger have contacted touch sensitive surface **112** and may for example result in execution of a first action for a first finger touch type and a second action for a second finger touch type. For example, U.S. patent application Ser. No. 13/887,711 entitled "Using Finger Touch Types to Interact with Electronic Devices", filed on May 6, 2013 and incorporated by reference in its entirety describes such an application.

Capacitive data can also provide data that can be useful in analyzing contacts with a touch sensitive surface **112**. For example in commonly assigned and co-pending U.S. patent application Ser. No. 14/191,329, entitled "Using Capacitive Images for Touch Type Classification," filed on Feb. 26, 2014, describes in part a method of interaction between a user and an electronic device having a touch sensitive surface. In one aspect of this, a capacitive image is accessed comprising capacitive image data corresponding to capacitances at a plurality of locations on the touch-sensitive surface, the capacitances varying in response to a physical touch on the touch-sensitive surface The capacitive image data is processed and it may be possible to determine a touch type for the physical touch based on the processed capacitive image data. It may also be useful to, where possible to do so, maintain heuristic data regarding such objects.

Touch intensity data can also provide information that can be useful to processor **150** in determining how to react to a touch contact. Such touch intensity data can be determined based upon the touch intensity between object **118** and touch sensitive surface **112** which in turn can be determined for example based upon capacitance, resistance or shear force measurements. Additionally, touch intensity data can be determined based upon sensed variations in an amount of force applied through indicator **130** against touch sensitive surface **112** which can be sensed in the various ways described in greater detail above and in any other know manners for sensing force applied against a surface.

In the embodiment of FIGS. **1** and **2** an object classification unit **180** is provided that can be used to determine object characterization information. Furthermore, object classification unit **180** may transmit contact intensity data characterizing an amount of force applied by or through object **118** during contact. This can be done in one embodiment by providing touch intensity data that corresponds to each element of touch intensity data or by sampling, mathematically processing or otherwise processing force data to characterize the amount of force applied during a frame. Such information can be used by processor **150** in understanding the proper response to contact with an object **118**.

It will be understood that operating processor **150** in a manner that continuously monitors frame data from touch sensor system **110** while simultaneously operating processor **150** to monitor and analyze signals from vibration sensor system **120** in real time creates a significant burden on the processor **150** that can make the processor **150** perform functions more slowly and that can reduce the efficiency of processor **150** and, where a portable power supply is used this can have the effect of lowering the run time between charging.

An alternative option of initiating sampling of audio sensor **124** or an accelerometer **126** only after contact is sensed by a touch sensitive surface **112** risks creating conditions where important components of the vibro-acoustic, capacitance and touch intensity patterns are not captured. This limits the usefulness of the information captured after touch is detected.

What is needed therefore is a way to allow touch sensitive device **100** to make vibration data representing conditions that are sensed by vibration sensor system **100** available to processor **150** when needed while enabling processor **150** to operate effectively and efficiently.

FIG. **3** shows one embodiment of touch sensor system **110** that allows desired information captured by vibration sensor system **120** to be preserved and available while allowing efficient use of processor **150**. In the embodiment of FIG. **3**, sensor hub **200** receives vibration signals **230** from vibration sensor system **120** that are representative of conditions that are incidental to contact between touch sensor system **100** and object **118**. In this embodiment, vibration sensor system **120** has a vibration sensor **122** that includes an audio sensor **124**, such as a microphone that senses acoustic signals that are representative of vibrations or pressure changes carried by air or any other medium within which touch sensitive device **110** is operated and an accelerometer **126** that is used to sense vibrational signals carried through touch sensitive device **100**. In this embodiment, signals from audio sensor **124** and accelerometer **126** are received by vibration sensor system driver **128** which provides a vibration signal **230** to sensor hub **200** and in this embodiment sensor diver **210**. One or both of vibration sensor system driver **128** and a sensor driver **210** shown in this embodiment as being in sensor hub **200** can optionally be used to perform any desired processing or organization of vibration signal **230**. Sensor driver **210** causes vibration data **232** to be stored in a sensor data memory **250** which in the embodiment illustrated in FIG. **3** is located in memory system **160**. Vibration data **232** may also include any other data or metadata associated with vibration data **232** as well as any other data detected by vibration sensor system **120** or otherwise provided by vibration system driver **128**. Vibration data **232** may also include other data determined or derived by sensor driver **210** based upon conditions that are sensed by vibration sensor system **120** or otherwise included in vibration signal **230**.

Touch sensor system **110** has a touch sensor system driver **116** that generates touch sensor system signals **240** and frame data **244** based upon conditions sensed at touch sensitive surface **112**. Frame data **244** travels to processor **150** for analysis while touch signals **240** are directed to sensor driver **210**. Such touch signals **240** include signals that sensor driver **210** can use to determine the presence or absence of any touch against touch sensitive surface **112**. Sensor driver **210** performs any desired processing of touch sensor system signals **240** and provides touch data **242** which includes data indicative of touch sensing events including but not limited to times at which contact between touch sensitive surface **112** and an object **118** occurs. In one non-limiting example of this sensor driver **210** provides touch data **242** having indicating whether or not touch sensor signal **240** indicates that there is contact between touch sensitive surface **112** and an object **118**. For example, where no contact exists touch data **242** may have a value of 0 and where contact exists the touch data may have a value of 1. Touch data **242** may also include or be based upon frame data **244** and any metadata associated with frame data **244** as well as any other data detected by touch sensor system **110** or otherwise provided by touch sensor system driver **116**. Touch data **242** may also include other data determined or derived by sensor driver **210** based upon conditions that are sensed by touch sensor system **110** or otherwise included in touch sensor system signal **240**.

In other embodiments, touch sensor system **110** may capable of detecting when an object **118** is within a range of non-touching positions proximate to touch sensitive surface **112** and may include signals indicating the proximate presence of the non-touching object **118**. Such a touch sensor system **110** may provide touch sensor system signals **240** including signals from which sensor data driver **210** can determine when an object **118** such as a finger, is hovering within the range of non-contact positions proximate to touch sensitive surface **112** in which object **118** can be detected. In this manner, sensor data driver **210** can provide touch data **242** indicating when object **118** is approaching contact with touch sensitive surface **112**, lifts from contact with surface **112** or otherwise changes position within the range of non-touching positions.

In operation, a controller shown here as sensor driver **210** causes touch data **242** to be stored in temporal association with vibration data **232** in a sensor data memory **250**. At an initial level, this relieves processor **150** from having to directly process and manage the storage of touch data **242** while preserving such information for use by processor **150** when desired. This may be used, for example, to allow processor **150** to determine whether, for example, data extracted from ongoing analysis of frame data **244** provides sufficient information to make confident decisions about actions that processor **150** is to undertake. Where this data does not provide sufficient information or where processor **150** determines that such information may be otherwise useful, processor **150** can supplement decision making processes by way of analysis of vibration data **232**.

Accordingly, it will be understood that having vibration data **232** available to processor **150** is particularly valuable when necessary. However, in the management of a touch sensitive device **100** it is also particularly valuable that relevant portions of vibration data **232** be accessible to processor **150** in a rapid and efficient fashion.

The temporal association between vibration data **230** and touch data **246** with touch events makes it possible for processor **150** to identify and examine relevant portions of sensor system data with the desired rapidity and efficiency. For example, it will be understood that when a signal from audio sensor **124** or accelerometer **126** is useful for classifying the touch type (i.e., touch means), vibration data **232** sampled immediately around and after the touch down event is typically of greatest interest. Accordingly, by maintaining vibration data **232** that is in some type of logical association with touch data **242** that indicates a temporal association between vibration data **232** and touch data **242** data is preserved in a manner that can be quickly accessed by processor **150** and efficiently used to identify one or more segments of vibration data **232** of interest at a particular time. Any stored vibration data **232** that is not temporally stored in association with touch data **242** related to a touch event of interest can be ignored, discarded, overwritten or used for other purposes if appropriate.

FIG. **4** illustrates a first example of the contents of a sensor data memory **250** in which sensor data **252** including vibration data **232** and touch data **242** is organized into a data structure **260**. In this embodiment, sensor data structure **260** stores sensor data **252** in sequential manner using, as illustrated here a series of samples arranged from oldest in time to newest. In this regard sensor data memory **250** can use a First-In-First Out (FIFO) data storage approach or in a First-In-Last-Out (FILO) data storage. Other approaches are possible and these include, but are not limited to, overwriting the oldest sensor data **252** in the sequential data record with the newest sensor data **252** and so that data in the sequential data record is recorded in a circular and continuous fashion. Sequential data structure **260** may also operate as a buffer that simply that stops recording data when out of memory or that erases sensor data **252** at device or session shutdowns or restarts or when modes or application programs are changed. Although data structure **260** is illustrated as a sequential data structure in this embodiment, other known logical data structures may be used so long as a temporal association between vibration data **232** and touch data **242** is maintained.

In this example data structure **260** has a vibration data record **262** with a sequence of numbers representing vibration data **232** sampled during a sequence of sample periods **264** and a touch data record **266** including touch data **242** for each of sample periods **264**. In this way, a temporal association is provided between vibration data **232** and touch data **242** within each sample period **264**. Other arrangements can be used.

In operation, processor **150** can identify a relevant segment of vibration data record **262** by locating transitions in the state of touch data record **266**. For example, in the embodiment illustrated in FIG. **4**, processor **150** can determine that segment **268** of vibration data record **262** has data that is of potential interest by locating the transition from a value of 0 (representing for example no object in contact with touch sensitive surface) to 1 (representing for example an indication that an object is in contact with touch sensitive surface) in the touch data record **266** and by initiating analysis of data from vibration data record **262** beginning with data from vibration data record **262** that is associated with or located based upon a detected transition in touch data record **266**. This, in turn, allows processor **150** to ignore vibration data **232** in portions of vibration data record **262** that are outside of segment **268**.

In the example shown in FIG. **4**, a vibrational stimulation **254** of vibration sensor system **120** is illustrated as an analog waveform that is associated in time with vibration data **232** and touch data **242**. In FIG. **4**, vibration data **232** is representative of vibration sensed by vibration sensor system **120** in response to vibrational stimulation **254**. As can be seen in FIG. **4** single channel vibration signal **254** has three portions **254***a*, **254***b* and **254***c* where vibrations are sensed that are above a general baseline and vibration data record **262** has vibration data with three different segments **265**, **267**, and **268** with data that reflects these conditions. If asked to analyze such vibration data **232**, processor **150** would have to perform significant processing to determine which of segments **265**, **267** and **268** is a segment of interest in making operating decisions. This is time consuming, processor cycle consuming, power consuming and can lead to errors.

However, as is shown in FIG. **4**, in this embodiment touch data **242** occurring during vibrational stimulation **254** is also stored in temporal association vibration data **232**. For the purposes of this example, touch data **242** is illustrated as a single channel of data with a 0 being indicative of a time where no contact is sensed between touch sensitive surface **112** and an object **118** and with a 1 representing a time at which contact between touch sensitive surface **112** and an object **118** is sensed.

This arrangement allows processor **150** to examine touch data record **266** to determine which portions of touch data **242** in touch data record **266** are indicative of a touch contact with touch sensitive surface **110**. Once that touch data **242** indicative of such touch contact is found, processor **150** can use the temporal association between the determined touch data **242** and vibration data **232** to identify a segment of vibration data record **262** that is of interest.

In the example of FIG. **4**, processor **140** can begin analysis of sensor data **252** by analyzing touch data **242** in touch record **266** at a time that is known to be before the time of the touch contact that is being analyzed. In this example, processor **150** can quickly determine that the vibration data **232** in segments **265** and **267** are not related to the touch event of interest in that portions **265** and **267** of vibration data record **262** were obtained at a time that touch sensitive surface **112** was not in contact with object **118** and can perform analysis on segment **268**.

In FIG. **4**, segment **268** is shown beginning with vibration data **232** that is temporally associated with a transition of touch data **242** from data that indicates no contact between touch sensitive surface **112** and object **118** to a data that indicates that contact between touch sensitive surface **112** and object **118**. Here this is illustrated by a transition between touch data having a value of 0 to touch data **232** having a value of 1. Similarly segment **268** ends with vibration data **232** that is temporally associated with a transition of touch data **242** from data that indicates contact between touch sensitive surface **112** and object **118** to a data that indicates that no contact between touch sensitive surface **112** and object **118**. Here this is illustrated by a transition between touch data having a value 1 to touch data **232** having a value of 0.

This is not the only approach that can be used for this purpose. In other embodiments, processor **150** may define a segment vibration data **232** for consideration to include, for example and, without limitation, a predetermined extent of vibration data **232** following the occurrence of a transition in the touch data record **264**. In other non-limiting alternatives the extent of the vibration data record **262** considered by processor **150** may be variable and may continue until processor **150** has received sufficient information to make particular determinations such as, for example, determinations classifying contacts against touch sensitive surface **112**. In such an example, processor **150** can determine to end segment **268** when processor **150** reaches a determination that classifies a contact, a determination that vibration data **232** data does not support a particular classification for the contact or as illustrated here, when an indication of contact with a touch sensitive screen is no longer present. Other criteria can be used for determining the end of a segment of interest **268**.

Similarly, it will be appreciated that the start of a segment of interest **268** may begin with vibration data **232** that is associated with sample periods **266** other than an individual one that is associated with a transition in touch data **242** in the touch event data record **266**. For example, and without limitation there may be a phase or sampling period difference between vibration data **232** in vibration data record **262** and touch data **242** in touch data record **264**. In such cases, or for other reasons, processor **150** therefore may determine the start of a segment **268** of vibration data **232** based upon a detected transition in the touch data record **264** but may include vibration data **232** from sample periods **266** beginning either before or after a change in the touch data **242** in the touch data record **264**.

It will be appreciated that vibration data **232** illustrated in vibration data record **262** and touch data **242** illustrated in touch data record **264** in FIG. **4** are for the purpose of illustration and explanation only and are not limiting. For example and without limitation, vibration data record **262** may include any types of data obtainable by sensing system **130**, including processed forms of such data, combinations, calculations made using such data and derivatives thereof. Similarly, touch data record **264** may include without limitation touch data **232** that characterizes or that can be used to determine characteristics of any of the following information:

Event type (e.g., hover/proximate finger, no object, touching object, multiple objects)

X/Y coordinates of any fingers on the screen;

orientation of any fingers on the screen;

first and second moments of any touch blobs (fingers) on the screen;

pressure of any fingers on the screen;

raw capacitive image of the touchscreen; and/or

a filtered/processed capacitive image of the touchscreen

and may also include processed forms of such data, combinations, calculations made using such data and derivatives thereof.

Processor **150** can use data stored in sensor data memory **250** to trigger different behaviors in order to better optimize operation of touch sensitive device **100**.

The use of the sequential data structure **260** as illustrated is optional and any data configuration or algorithmic or other logical organization allows storage of sensor data **262** which, that includes data characterizing vibrations sensed during a plurality of sequential sample periods along with some form of a logical association between touch data **264** and vibration data **232** such that the touch data can be used to identify a segment of vibration data **232** that may have been sensed at a time of contact between an object **118** and touch sensitive surface **112**.

FIG. **5** illustrates a sensor data memory **250** having another embodiment of a sensor data record **252** that may be used in conjunction a touch sensitive device such as touch sensitive device **100** of FIGS. **1-3**. However, in this embodiment, touch sensitive device **100** is capable of sensing when a finger or other object **118** is positioned within a range of non-contact positions that are proximate to touch sensitive surface **112**. In one embodiment, this can be done, for example, using an array of sensing elements **114** that are capable of sensing capacitance changes as a finger or other object is brought closer to touch sensitive surface **112**. In other embodiments, other sensors such as infrared or visible light sensors or imagers can be used for this purpose.

In this embodiment, a sequential data structure **260** is used that stores vibration data **232** and touch data **242** that may be generated when touch sensor system **110** shown above is capable of sensing when an object **118** such as a finger is positioned proximate to but not in contact with touch sensitive surface **114**. As is illustrated in FIG. **5**, in this embodiment, sequential data structure **260** takes the form of a supplemental touch data record **272**. Proximity data record **272** includes three different entries, an "H" data point indicating that an object **118** such as a finger is within a range of sensing positions relative to touch sensitive surface **112** and is maintaining a distance from touch sensitive surface **112** but has not contacted touch sensitive surface **112**, a "D" data point indicating object **118** is moving toward touch sensitive surface and a "U" data point indicating that object **118** has broken contact with touch sensitive surface **112** and is moving away. Processor **150** can therefore use the "D" data point in this embodiment in identifying when to begin segment **268** or as is shown in FIG. **6**, by beginning segment **268** based upon the "H" data point, it becomes possible to define segment **268** to include sensing signal data **232** for sample periods **264** that begin as or just before a vibrational/acoustic signal **252** created by contact between touch sensitive surface **112** and object **118** begins. This can be used to provide one or more of the advantages described above.

Optionally, in such an embodiment, upon detection of a hover/or downward finger event, components of vibration sensor system **120** such as audio sensor **124** and/or accelerometer **126** can be turned on, or put into a high speed/high fidelity mode. Conversely, when an object is lifted from contact with touch sensitive surface or sensed moving away from touch sensitive surface **112** ("touch up event"), audio sensor **124** accelerometer **126** can be turned off, put into a low power mode, put into a low speed/low fidelity mode. This advantageously reduces power consumption and memory requirements.

FIG. **6** shows a sensor data memory **250** having another embodiment of a sequential data structure **260**. In this embodiment both touch data record **242** having touch data **232** stored therein and a supplemental touch data record **272** is used to record any other information obtained by sensor system **108** regarding the proximity of an object **118** to touch sensitive surface **112** or contact between object **118** and touch sensitive surface **112**. Without limitation supplemental touch data record **272** can include as illustrated, separate records with touch data **232** in a touch data record **264**, a proximity data record **2'72***p*, an x-axis data record having data indicating an x-axis position of the detected contact **272***x*, and a y-axis data record having data indicating a y-axis position of the detected contact **272***y*. The x-axis data **272***x* and *y*-axis data **272***y* indicate a coordinate of contact between object **118** and a touch sensitive surface **114** and, optionally, can be used to indicate a coordinate of any sensed proximity.

As is also shown in FIG. **6**, vibration data **262** may include data that is in one or more axis such as where audio sensors are made directional or where three axis sensors are used to sense vibration. In the example shown in FIG. **6**, data from a three axis sensor is organized into an x-axis vibration data record **262***x*, a y-axis vibration data record **262***y*, and a z-axis vibration data record **262***z*. Here all are shown in temporal association with touch data in touch records **272***t*, **272***p*, **272***x*, and **272***y*. However, in other embodiments a temporal association may be necessarily maintained between two of these data records with other portions of such records used for other purposes by processor **150**.

It will be appreciated from FIG. **6**, that other types and kinds of data and metadata and data derived from either of vibration signals **230** and touch signals **240** and from other sources can be stored in memory **150** optionally in temporal association and that the records illustrated in FIG. **6** are exemplary and not limiting.

In the embodiment of FIGS. **1-3**, sensor data memory **250** is illustrated being located in memory system **160**. However, in other embodiments, sensor data memory **250** can be located in other portions of a touch sensitive device **100**. For example, in the embodiment illustrated in FIG. **7**, sensor data memory **250** is illustrated as being located in sensor hub **200**. This advantageously allows vibration signals **230** as well as touch sensor system signals **240** to pass to sensor hub **200** where sensor driver **210** can convert these as necessary into vibration data **232** and touch data **242** for storage as vibration data record **262** and touch data record **266** in sensor data memory **250** without burdening main bus **218** with high speed data flows.

In still another embodiment illustrated in FIG. **8**, sensor data memory **250** is located in vibration sensor system **120** with touch sensor system signals **240** or touch sensor signal data **242** passing to sensor hub **200** and with touch sensor system signals **240** or touch data **242** then being passed along to vibration sensor system **120** for storage in sensor data memory **250** in temporal association with vibration data **232**. Touch sensor system signals **240** or touch sensor signal data **242** can be further processed by vibration sensor system driver **128** or sensor hub **200** before storage in sensor data memory **250**. Such processing can include for example and without limitation converting touch sensor system signals **240** into touch sensor signal data **242**, using touch sensor signal data **242** to create a touch data record, or creating a temporal association between vibration data record **262** and touch data record **266**. This embodiment allows the use of memory circuits (not shown) that may be available in vibration sensor system **120** and optionally can also leverage other capabilities of components of vibration sensor system **120**. Similarly, in this embodiment touch sensor driver **116** can be used to process touch data **242** to from touch data record **266**. In some embodiments of this type, vibration sensor system driver **128** can also be used to provide instructions or synchronization signals to touch sensor system **110**. Here too, this approach allows a sensor data memory **250** to be created without necessarily burdening main bus **220**.

In a further embodiment illustrated in FIG. **9**, sensor data memory **250** is located in touch sensor system **110** with vibration signals **230** or vibration data **232** passing to sensor hub **200** and with vibration signals **230** or vibration data **232** then being passed along to touch sensor system **110** for storage in sensor data memory **250** in temporal association with touch sensor signal data **232**. Vibration signals **230** or vibration data **232** can be further processed by touch sensor system driver **116** or sensor hub **200** before storage in sensor data memory **250**. Such processing can include for example and without limitation converting vibration signals **230** into vibration data **232**, using vibration data **232** to create a vibration data record **262**, or creating a temporal association between vibration data record **262** and touch data record **266**. Such an approach allows the use of memory circuits (not shown) that may be available in touch sensor system **110** and optionally can also leverage other capabilities of components of touch sensor system **110**. In some embodiments of this type, touch sensor system driver **116** can also be used to provide instructions or synchronization signals to vibration sensor system **120**. Here too, this approach allows sensor data memory **250** to be created without necessarily burdening main bus **218** which in this embodiment can be useful as in this embodiment main bus **218** is optionally used to carry all data from touch sensor **110** to processor **150**.

FIG. **10** illustrates yet another embodiment of the invention. As is shown in FIG. **10**, in this embodiment, sensor data memory **250** is located in processor **130** with touch sensor system **110** providing touch sensor signal data **240** or touch sensor signal data **242** to sensor hub **200** and with vibration sensor system **120** providing vibration signals **230** or vibration data **230** to a sensor driver **210** in processor **140** and with sensor driver **210** using vibration data **230** and touch sensor signal data **242** to create vibration data record **262** and touch data record **266** and to establish a temporal association between vibration data record **262** and touch data record **266** in a portion of processor **150** such as a cache memory or other memory of processor **150**. This allows a portion of processor **150** such as one core of a multi-core processor or an integrated I/O module to create as sequential data a structure **260** within sensor memory **250** having vibration data and touch data stored in temporal association without interfering or substantially interfering with the operations of processor **150**. In one embodiment of this type, sensor memory **250** is located in a cache memory of processor **150** and in this way allows very high speed access to the data stored in sequential data structure **260**.

As is also shown in this embodiment, vibration signal **230**, vibration data **232**, touch signal **240** and touch data **242** optionally can be provided to sensor data memory **250** through a direct data connection **280** so that main bus **218** is not burdened by such data flows, however other arrangements are possible in other embodiment. Additionally, as is shown in this embodiment, a separate sensor hub **210** is not required. It will be appreciated that in other embodiments, sensor data memory **250** can be stored in other components of touch sensitive device **100** such as for example and without limitation object classification unit **180**.

It will be appreciated that in other embodiments the functions ascribed to sensor driver **210** may be performed by more than one component such as by combined action of components such as touch sensor system driver **116**, vibration sensor system driver **120**, sensor hub **200**, processor **150** and memory **160**. In that sense sensor driver **210** may be located in part or in whole in any of these components.

Touch sensitive device **100** can take forms other than those described herein including but not limited to any type of digital equipment having a touch sensor system **110** and a processor **130** such as a micro-processor, micro-controller, or any other type of programmable control device, or a preprogrammed or dedicated processing or control system. Examples of such touch sensitive devices **100** include but are not limited to desktop computers, notebook computers, workstations, PDAs, web pads, and mobile phones (other than smartphones). Similarly, touch sensitive device **100** can take other forms such as the forms of standalone touch pads and track pads as well as systems that incorporate touch sensitive surfaces and **102** such as touch pads, graphics tablets and track pads. In this regard, it will be appreciated that while the components of touch sensitive device **100** are illustrated as being within a single housing **102**, this is optional, and these components may be located in separately housed components of touch sensitive device **100**. however, can take the form of a cellular telephone, personal computer, a display table, a personal digital assistant, a television or a touch sensitive graphic tablet typically has a touch sensitive surface **112** that is capable of sensing when an object has been brought into contact with touch sensitive surface **112**.

The embodiments according to the present invention as described above may be implemented in the form of program instructions that can be executed by various computer components, and may be stored on a computer-readable recording medium. The computer-readable recording medium may include program instructions, data files, data structures and the like, separately or in combination. The program instructions stored on the computer-readable recording medium may be specially designed and configured for the present invention, or may also be known and available to those skilled in the computer software field. Examples of the computer-readable recording medium include the following: magnetic media such as hard disks, floppy disks and magnetic tapes; optical media such as compact disk-read only memory (CD-ROM) and digital versatile disks (DVDs); magneto-optical media such as optical disks; and hardware devices such as read-only memory (ROM), random access memory (RAM) and flash memory, which are specially configured to store and execute program instructions. Examples of the program instructions include not only machine language codes created by a compiler or the like, but also high-level language codes that can be executed by a computer using an interpreter or the like. The above hardware devices may be changed to one or more software modules to perform the operations of the present invention, and vice versa.

Although the present invention has been described above in connection with specific limitations such as detailed components as well as limited embodiments and drawings, these are merely provided to aid general understanding of the invention. The present invention is not limited to the above embodiments, and those skilled in the art will appreciate that various changes and modifications are possible from the above description. Therefore, the spirit of the present invention shall not be limited to the embodiments described above, and the entire scope of the appended claims and their equivalents will fall within the scope and spirit of the invention.

What is claimed is:

1. A touch sensitive device, comprising:

a touch sensor system having a touch sensitive surface that senses contact made by an object to or proximate to the touch sensitive surface and that generates touch signals indicative of the contact sensed by the touch sensor system;

a vibration sensor system that senses vibrations that occur when the contact is made by the object to the touch sensitive surface and that senses vibrations that are not associated with the contact and that generates vibration signals indicative of the vibrations sensed by the vibration sensor system;

a sensor data memory; and

at least one controller adapted to receive the vibration signals and to cause vibration data indicative of particular vibrations sensed during each of a plurality of sample periods to be stored in a vibration data in the sensor data memory, wherein the controller is further adapted to receive the touch signals and to cause touch data to be stored in the sensor data memory in temporal association with the vibration data record, wherein the at least one controller provides a first portion of the vibration record data that is in temporal association with the touch data for the contact to a processor, and wherein the at least one controller does not provide a second portion of the vibration data that is not in temporal association with the touch data for the contact to the processor so that the second portion of the vibration data corresponds to vibrations that are not associated with the contact.

2. The touch sensitive device of claim **1**, wherein the vibration sensor senses at least one of vibrations of the touch sensitive device, vibrations of a medium proximate to the touch sensitive device and acoustic vibrations.

3. The touch sensitive device of claim **1**, wherein the vibration sensor comprises a touch sensor that senses conditions indicative of the touch.

4. The touch sensitive device of claim **1**, wherein the touch data is stored in a touch data record, and wherein the touch data indicates whether there is contact between the object and the touch sensitive surface during a sample period.

5. The touch sensitive device of claim **4**, wherein a duration of the sample periods is changed in response to a touch signal indicating the proximate presence of an object.

6. The touch sensitive device of claim **5**, wherein a sensor hub is joined to a main bus such that the sensor system data and touch data are provided to the sensor hub without passing through the main bus.

7. The touch sensitive device of claim **1**, wherein the touch sensor system is adapted to sense when the object is in a position that is proximate to but not in contact with the touch sensitive surface and generates a touch signal from which the controller further stores data in the touch data indicating the proximate presence of the object that is not in contact with the touch sensitive surface.

8. The touch sensitive device of claim **1**, wherein the temporal association comprises providing a data structure having vibration data representing sensed vibrations during a plurality of sequential sample periods having a logical association with touch data representing sensed contact with the touch sensitive surface during each of the plurality of sequential sample periods such that the touch data can be used to identify a segment of the vibration data that may have been sensed at a time of contact between an object and the touch sensitive surface.

9. The touch sensitive device of claim **1**, wherein the temporal association comprises providing a sequential data structure having vibration data representing sensed vibrations during a plurality of sequential or substantially sequential periods arranged in association with touch data associated with the sequential data structure such that the touch data can be used to identify a segment of the vibration data that may have been sensed at a time of contact between an object and the touch sensitive surface.

10. The touch sensitive device of claim **1**, wherein the sensor data memory is located in a sensor hub that is linked to the touch sensor system and the vibration sensor system.

11. The touch sensitive device of claim **1**, wherein the at least one controller comprises a touch sensor system driver and wherein the sensor data memory is positioned in the touch sensor system.

12. The touch sensitive device of claim **1**, wherein the at least one controller comprises a vibration sensor system driver and wherein the sensor data memory is positioned in the touch sensor system.

13. The touch sensitive device of claim **1**, further comprising sensor hub and wherein the at least one controller comprises a driver in the sensor hub and wherein the sensor data memory is positioned in the sensor hub.

14. The touch sensitive device of claim **1**, wherein the sensor data memory is at the processor and wherein the at least one controller is at least one of a touch sensor system driver, a sensor system driver and a driver in a sensor hub.

15. The touch sensitive device of claim **1**, further comprising object classification unit that analyzes a segment of the vibration data and the touch data to classify an object contacting the touch sensitive surface.

16. The sensitive device of claim **1** wherein the vibration is an acoustic vibration.

17. A sensor system for use in a touch sensitive device, comprising:

a first sensor adapted to sense a first physical condition experienced at the touch sensitive device and to generate a first sensor signal, the first physical condition associated with when a contact is made by an object proximate to or in direct contact with the touch sensitive surface and that generates the first sensor signal; and

a sensor driver adapted to receive the first sensor signal and store first sensor data in a sensor data memory representing conditions, including the first physical condition, sensed during each of a sequence of sample periods and further adapted to receive a vibration signal indicative of a plurality of conditions, including the first physical condition and a second physical condition experienced at the touch sensitive device, and to store second sensor data for the vibration signal in the sensor data memory in temporal association with the first sensor data, wherein the second physical condition is independent of the first physical condition;

wherein the sensor driver is adapted to provide a first portion of the first sensor data and the second sensor data that are temporally associated together in association with the first physical condition to a processor, and wherein the sensor driver is adapted to not provide a second portion of the first sensor data and the second sensor data that are temporally associated together in association with the second physical condition to a processor.

18. The sensor system of claim **17**, further comprising a second sensor adapted to sense the first and second physical condition experienced at the touch sensitive device and to generate the second sensor signal.

19. The sensor system of claim **17**, wherein sensor data memory is located in one of the first sensor, the second sensor, a sensor hub and the processor.

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